City of Baltimore

Low Level Sewershed Study

Baseline Analysis & Capacity Assessment Report

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EXECUTIVE SUMMARY

As part of Baltimore City Project No. 1029, Hazen & Sawyer, Patton Harris Rust & Associates and Hatch Mott MacDonald have conducted a Baseline Analysis and Capacity Assessment using the calibrated hydraulic model for the Low Level sewershed. This report identifies areas that experience surcharged conditions or overflows for seven different design storms.

The modeling software selected for the City of Baltimore Collection System Evaluation and Sewershed Plan is InfoWorks CS, by Wallingford Software, Ltd. The model includes all manholes, junctions, and structures along modeled sewer lines and all control structures (e.g. sluice gates and pumping stations) existing in the system as required to accurately portray the collection system. The Low Level Sewershed model includes over 473,361 linear feet of pipe, 3,149 nodes and three primary pumping stations.

The Consent Decree (CD) defines what should be included in the baseline and future conditions models. Baseline conditions are defined by the CD as the conditions in effect during the flow monitoring period including the effects of all Paragraph 8 projects. Since the Low Level sewershed had no Paragraph 8 projects that affect the hydraulic performance of the collection system, the baseline model represents the existing conditions at the time of flow monitoring. The future conditions model includes the effects of demographic changes (population and jobs), expected pipe deterioration and the effects of any planned capital improvement projects. The future conditions model will include population and jobs projections for the Year 2025 based on data from the Baltimore Metropolitan Council. The hydraulic impact of pipe deterioration is represented by increasing groundwater infiltration by 10% compared to baseline. The only capital improvement project that is incorporated into both the baseline and future conditions models is an upgrade at the Eastern Avenue Pump Station to provide automated pump control to replace the previous manual only pump operation.

The baseline and future conditions hydraulic models were run for both dry weather flow and wet weather flow. Dry weather flow (DWF) results for both baseline and future conditions are depicted on the mapping figures included with this report. No DWF overflows occurred under either baseline or future conditions but there were surcharged conditions at various locations in the collection system. Wet weather results for both baseline and future conditions were determined under the seven standardized design storms. These design storms include, the 3-month, 5-hour storm (the duration equal to the time of concentration for the sewershed) and the 1, 2, 5, 10, 15, and 20-year, 24 hour duration storms. All simulated result in sanitary sewer overflows (SSOs). The locations and volumes of these SSOs are also included in the mapping figures included in the report. This report also includes a Return Period Analysis (RPA) for the seven design storms. The results of the baseline and future conditions RPA are included on mapping figures as well.

Another analysis included in this report includes mapping all components of the wastewater collection system that restrict the flow of wastewater through the collection system that cause or contribute to, or are likely to cause or contribute to, overflows from the collection system. The results of this analysis under baseline and future conditions are depicted on maps included with this report.

1.0 Introduction

The City of Baltimore has selected consultants to perform comprehensive investigations and analyses for each of the City's eight sewersheds. This report details the baseline analysis and capacity assessment for the Low Level sewershed using the previously developed calibrated hydraulic model. Details concerning the Low Level calibrated hydraulic model can be found in the *Low Level Model Development and Calibration Report (January 2009)*. This analysis, as well as the analyses conducted for the other sewersheds, will enable the City to comply with its September 2002 Consent Decree (CD). The goal of the CD between the City, the United States Environmental Protection Agency and the State of Maryland Department of the Environment is to reduce the number of sanitary sewer overflows (SSOs) within the City. The ultimate goal of this baseline analysis and capacity assessment is to identify deficiencies in the Low Level collection system under both baseline conditions and future conditions.

To help facilitate consistency and common methodological approaches, the City created the BaSES (Baltimore Sewer Evaluation Standards) manual. This manual describes how the various components of the overall collection system evaluation and sewershed planning phases should be approached by each consultant team. The baseline analysis and capacity assessment were performed in compliance with the criteria defined in Section 7.6 of the BaSES manual.

1.1 Project Description

The Low Level sewershed is located in the downtown and adjacent harbor areas of the City of Baltimore. The sewershed includes dense residential areas, heavily industrial areas and the downtown central business district. The diverse land uses and significant industrial areas make the Low Level sewershed unique compared to the City's other sewersheds. The Low Level sewershed includes 13.3 square miles of contributing drainage area and a sewer network of approximately 82 miles of gravity sewer ranging from 10-inches to 84-inches in diameter. Two primary Interceptors (East and West) convey flow to the Eastern Avenue Pump Station (EAPS), which in turn pumps to the Main Outfall Interceptor as shown in Figure 1.

Figure 1: Low Level Interceptors and Eastern Avenue Pump Station

1.2 Consent Decree Requirements

The CD between the City of Baltimore, the United States Environmental Protection Agency and the Maryland Department of the Environment stipulates that the hydraulic model must be capable of determining:

1. The flow capacity of each of the pumping stations in the collection system;
2. The flow capacity of each pumping station with its back-up pump out-of-service;
3. Peak flows for each pumping station during storm events of a magnitude of up to 20 years;
4. Likelihood and location of overflows(s) within a service area under high flow conditions, including pumping station service areas where the pumping station's back-up pump is out-of-service, and considering available wet well capacity, off-line storage capacity, and normal in-line storage capacity.

Paragraph 9.C of the CD states that it is necessary to determine the range of storm events for which the collection system in its existing condition can convey peak flows without the occurrence of sanitary sewer overflows. As part of the analyses, all modeled components of the collection system that cause or contribute to flow restrictions or that have the potential to cause or contribute to overflows are identified.

As specified in CD and the BaSES Manual, the calibrated hydraulic model, approved by the Technical Program Manager, shall be used to evaluate the collection system under baseline conditions and future conditions for seven design storms. These design storms include a 3-month, 5-hour storm (duration equal to the time of concentration of the sewershed) and the 1, 2, 5, 10, 15, and 20-year, 24 hour design storms.

Baseline conditions are defined as the existing conditions at the time of the flow monitoring and all completed Paragraph 8 projects (none in Low Level sewershed). Future conditions represent the condition of the collection system in the year 2025. The effect of pipe deterioration for future conditions is accounted for by increasing the groundwater infiltration by 10 % compared to baseline conditions. The future conditions model also includes projections of expected population and employment changes. Finally, any proposed capital improvement project planned that will have a hydraulic impact on the performance of the collection system to be completed before 2025 are included in the future conditions model.

2.0 Hydraulic Model

2.1 Hydraulic Model Network

As stated in the CD, the modeled network shall include all force mains, major gravity lines, and pumping stations and their respective related appurtenances. The CD defines major gravity lines as:

- all gravity lines ten inches in diameter or larger;
- all eight-inch lines that convey or are necessary to accurately represent flow attributable to a service area in each of the Collection System's sewershed service areas;
- all gravity lines that convey wastewater from one pumping station service area to another pumping station service area; and
- all gravity lines that have caused or contributed, or that the City knows are likely to cause or contribute, to capacity-related overflows (utilizing the Water in Cellar (WIC) database).

The City selected InfoWorks CS, by Wallingford Software, Ltd., as its hydraulic modeling software for the City's Collection System Evaluation and Sewershed Plan. An evaluation team for the City selected InfoWorks as the modeling software best suited for the City of Baltimore system. The version used in this analysis was InfoWorks CS 10.0.

Development of the calibrated model required the collection of accurate information on the sewer network elements and the performance of the system through flow and rainfall monitoring. The City provided a "macro-model" as an initial starting point for development of the calibrated model. Starting from this point, all sewer network elements (pipes, manholes, pumps, etc) were verified based on a combination of field survey and other existing data sources. New survey data for sewer network elements were obtained in the NAD83 Maryland State Plane Coordinate System horizontal datum with elevations in the NAVD88 vertical datum. The horizontal and vertical datums were both in units of U.S. Survey Feet. Existing elevation data sources were converted to these datums as necessary. The collection of field data is still currently ongoing and will be incorporated into the calibrated model as it becomes available. The collected rainfall and flow monitoring data provided spatially distributed rainfall and flow measurements at key points in the collection system for calibration efforts. A more detailed description of the development of the hydraulic model is contained in the *Low Level Model Development and Calibration Report (January 2009)*.

The Low Level hydraulic model includes 473,361 linear feet of pipe, 3,149 nodes and three primary pumping stations. Figure 2 illustrates the hydraulic model network color-coded by pipe diameter.

2.2 Hydraulic Model Calibration

2.2.1 Summary of Dry Weather Calibration

Dry weather flow (DWF) was distributed to the hydraulic model based on three different flow types. DWF is composed of base sanitary flow (BSF) and ground water infiltration (GWI). BSF represents sanitary flow from sources connected directly to the sanitary sewer system. The total BSF flow is composed of population based sources (residential areas) and non-population based sources (commercial and industrial areas). GWI represents flow that constantly infiltrating into the collection system through structural defects or other means. These three DWF components (population based BSF, non-population based BSF and GWI) were input separately into the hydraulic model. The GWI was defined as a constant inflow so all flow factors for GWI were set to 1.00. BSF was input into the hydraulic model with a varying diurnal pattern developed from the Sliicer analysis of the DWF monitoring data. Few adjustments were necessary for the simulated DWF results to reasonably match the DWF monitoring data. Comparisons between predicted and observed DWF were quantified in tabular form and visually through observed versus predicted plots at each flow monitoring location.

To establish a DWF calibration standard, three DWF weeks (seven continuous dry weather days) were identified from the flow monitoring data. Since these three DWF weeks occurred throughout the monitoring period, they provided broadly applicable standard for the simulated dry weather results. This approach provided a means to evaluate the variability of GWI levels and any variations in diurnal patterns for each flow meter. If only a single DWF week was used for comparison, there would be less confidence in the model's DWF response during other times of the year when the GWI may vary significantly. In the future, the agreement between the measured and simulated DWF responses could be further improved if sufficient data becomes available to identify seasonal GWI patterns. These consistent patterns could be entered into InfoWorks to allow the model to account for variable GWI.

The DWF results of the calibrated model agreed favorably with the calibration criteria specified in the BaSES manual in most cases. When disagreement existed between the calibrated model and the flow meter data it typically involved meters that are highly influenced by the EAPS. Since the EAPS was manually operated during the flow monitoring period, it was difficult to precisely match the modeled pump operation to the sometimes unpredictable manual operations. However, even flow meters under the influence of EAPS generally still met the DWF calibration requirements

2.2.2 Summary of Wet Weather Calibration

Following completion of the dry weather calibration, wet weather flow (WWF) calibration was initiated. The capture coefficients (R-Values) that were calculated by Sliicer were applied to the model's subcatchments. The R-Value represents the percentage of the total rainfall volume that turns into flow in the collection system. The first model runs were based on InfoWorks default values for basin slope and basin width and initial values of 0.015 for runoff routing values (roughness factor). After reviewing the results for the various storm events, different SWMM RUNOFF variables were adjusted to improve correspondence between the simulated and measured wet weather results.

Despite some complicating factors listed below, the overall WWF calibration resulted in acceptable agreement between measured and simulated results. However, for some meters the results of the WWF simulation did not match the measured flow meter data within the WWF calibration criteria. There are two primary causes for the divergence between the measured and simulated WWF results:

- Difficulty in having the calibrated model recreate the manual operations at the EAPS during wet weather events, and
- Variability throughout the year in how different meter basins responded to wet weather conditions (widely changing R-Values).

Although many flow meter basins revealed highly variable R-Values, only a single, average R-Value could be entered into the hydraulic model. Figure 3 illustrates the R-Values utilized throughout the Low Level sewershed. The total annual infiltration volume (representing the 12-month monitoring period), normalized to gallons per inch-diameter-mile for each of the meter basins, is shown in Figure 4.

To attempt to accommodate the variable operation of the EAPS, several simplifying assumptions were made to model the EAPS pump operation. One simplifying assumption was to assume a set pumping capacity during dry weather conditions. Most DWFs at the EAPS are handled by a single pump for most conditions. However, since each of the pumps at the EAPS has differing pump capacities, no completely consistent pumping rates were observed. To account for this situation, the dry weather pump capacity of the EAPS was set at 38 mgd for all DWF conditions. In addition, the pumping capacity of the EAPS under two-pump simultaneous and three-pump simultaneous operation was set by examining the EAPS spirograph data.

To understand the pump operation at EAPS, the daily pump logs were reviewed. These logs recorded the daily cumulative pump run times for each of the pumps and the total flow volume pumped. All of the daily pump logs were compiled for the month of September 2006. These results demonstrated that no consistent pattern of operation could be defined. For the purposes of model calibration, the pumps at EAPS were defined according to the most typical or average operation at the station.

For model calibration, it was determined to be more important to accurately match the wet well levels than to precisely match the individual pump operations. This was also the more critical component to optimize since the backwater effect of the wet well level can have a significant effect on a large portion of the Low Level collection system. Finally, the focus on the EAPS wet well level ensures that the upstream collection system is properly calibrated. Currently, an upgrade to the EAPS is underway that will establish an automated control system to automatically optimize pump station operations. That control logic will be incorporated into the Low Level alternatives analysis to ensure that the simulated EAPS pump operations will match those soon to be put in place.

In summary, the hydraulic model for the Low Level sewershed was developed in accordance with the Consent Decree requirements and using procedures outlined in the BaSES manual. The sewer network was constructed using data verified by field inspection when possible and based on the results of the flow monitoring effort. Calibration efforts proved largely successful in spite of the complicating issues of modeling the manual operation of the EAPS accurately and a highly diverse response to rainfall for some meter basins. However, when examined in total the model reasonably replicates the performance of the actual sewer system. As a result the hydraulic model was considered calibrated and was subsequently used as a basis for the baseline analysis and capacity assessment described herein.

3.0 Baseline Analysis and Capacity Assessment

3.1 General

The CD defines baseline conditions as those existing conditions during the flow monitoring including the effects of the completion of Paragraph 8 projects in the sewershed. Although the Low Level sewershed did not have any Paragraph 8 projects, an currently ongoing upgrade at the EAPS was incorporated into the baseline conditions. The baseline hydraulic model has been simulated during both dry weather and wet weather conditions to identify areas of the collection system that lack adequate capacity to pass the projected flows for the various design storm events. As previously mentioned, these design storms include the 3-month, 6-hour storm and the 1, 2, 5, 10, 15, and 20-year, 24 hour duration design storms. Maps have been created showing the results of the return period analysis and hydraulic flow restrictions.

3.2 Baseline Dry Weather Capacity Assessment

An assessment of the baseline conditions for dry weather capacity was completed and there are no overflows in the system during dry weather. However, there are portions of the collection system that do experience surcharge conditions during peak dry weather flows. The location of these surcharge conditions are highlighted in red as shown on Figure 5. Figure 5 displays the peak percent full for each pipe during dry weather. Surcharge conditions are most pronounced along the East Interceptor in the vicinity of the EAPS. The pipes that are 75 percent full or greater during peak dry weather flows are highlighted in orange on Figure 5. A pipe that is ¾ full during dry weather does not provide adequate capacity for future growth or wet weather flows. The pipe segments that are between 50-75 percent full during dry weather are highlighted in yellow on Figure 5. The main causes of the elevated water levels are generally that the EAPS wet well operates at a high elevation and this causes a backup effect for a distance up both the east and west interceptors.

3.3 Baseline Wet Weather Capacity Assessment

3.3.1 Storm Events

As stated earlier, there are seven design storms that were to be analyzed. These design storms utilize a rainfall total and distribution derived from the NOAA Atlas 14/NRCS reference. The total rainfall depths for these seven design storms are as follows:

- 3 Month – 1.19 inches
- 1 Year – 2.67 inches
- 2 Year – 3.23 inches
- 5 Year – 4.15 inches
- 10 Year – 4.97 inches
- 15 Year – 5.41 inches
- 20 Year – 5.82 inches

3.3.2 Baseline Return Period Analysis

One of the requirements of the CD is to run a Return Period Analysis (RPA) on each the seven design storms. In doing this, InfoWorks compares the surcharge state of the sewer system and any flooding based on each design storm and presents the minimum size storm required to surcharge and flood (cause an overflow) a pipe segment, along with the estimated flood volume. This is accomplished by selecting all of the simulations based on the design storms and loading them into the Grid Report results menu and selecting the RPA option in InfoWorks CS. The results of the baseline flooding RPA are presented in Figure 6.

3.3.3 Eastern Avenue Pumping Station Analysis

Currently, the EAPS has five constant speed pumps with capacities ranging from 32 MGD to 40 MGD. While there are five pumps at the station, only one pump typically runs during dry weather, and no more than three pumps were observed to run simultaneously during the flow monitoring period. One of these pumps is currently out of service for maintenance. An upgrade at the EAPS is currently ongoing. The EAPS upgrade is included in both the baseline and future conditions hydraulic model results.

The EAPS upgrade consists of the addition of SCADA connectivity for the station and the addition of operational control logic for the station's five primary constant speed pumps. The new control logic for the pumps will tie the on/off operation of each pump to defined wet well elevations. The control logic includes the following rules:

- **Lead Pump** On Level: -6.5 Off Level: -11
- **Lag Pump 1** On Level: -6.0 Off Level: -10.5
- **Lag Pump 2** On Level: -5.5 Off Level: -10.0
- **Lag Pump 3** On Level: -5.0 Off Level: -9.5
- **Lag Pump 4** On Level: -4.5 Off Level: -9.0

Initially, different pump sequences are defined for four different operational conditions: Dry Weather Conditions (Daytime and Evening) and Wet Weather Conditions (Daytime and Evening).

For the baseline assessment, two modeling scenarios were developed for the EAPS as per the BaSES manual:

- Scenario 1 - all five primary pumps were available; and
- Scenario 2 - four primary pumps available with one backup offline

These two scenarios were simulated for each of the seven design storms. This setup assumes that the collection system downstream of the EAPS (Outfall Basin) can accept the peak wet weather flows from the EAPS with up to five pumps operating at once. Once all of the individual sewershed models are combined for further analysis by the Technical Program Manager, an evaluation should be conducted to verify the flows can be handled by the collection system in the Outfall Basin. The peak flow rates and force main velocities for the EAPS are presented below in Table 1.

Four of the EAPS pumps discharge to a common 60” diameter force main while a fifth pump is connected to a separate 42” diameter force main. The pump connected to the separate 42” force main is considered the backup pump for this analysis. Both EAPS force mains connect to a 99” diameter gravity line in the Outfall Basin that eventually connects to the Outfall Interceptor for conveyance to the Back River Treatment Plant. It is important that the velocities within the force mains do not become too elevated to prevent excessive head on the pumps and protect the system from scour effects. For the capacity analysis of the force mains, velocities greater than 7 fps are considered excessive. With the backup pump offline, the 5-year through 20-year storm events result in peak velocities equal to 7.0 fps.

Table 1 – Eastern Avenue Pump Station Results (Baseline)

Design Storm	Peak Incoming Flow Rate (MGD)	Five Pumps Available			Four Pumps Available		
		Peak Discharge (MGD)	Peak Velocity (fps) in 42” FM	Peak Velocity (fps) in 60” FM	Peak Discharge (MGD)	Peak Velocity (fps) in 42” FM	Peak Velocity (fps) in 60” FM
DWF	59.8	39.4	not used	2.4	39.4	not used	2.0
3-month	60.5	80.8	not used	4.5	77.1	not used	4.5
1-year	88.8	109.5	3.5	4.5	105.0	not used	6.0
2-year	100.3	109.9	3.4	4.5	105.0	not used	6.0
5-year	114.4	109.9	3.5	4.5	128.0	not used	7.0
10-year	123.5	137.2	3.5	6.0	128.0	not used	7.0
15-year	127.7	137.2	3.5	6.0	128.0	not used	7.0
20-year	131.1	137.2	3.5	6.0	128.0	not used	7.0

3.3.4 Other Modeled Pump Stations

Two other pump stations were included in the Low Level model, and are the Locust Point Pump Station and the McComas Pump Station. These pump stations are both located upstream in the collection system and serve much smaller tributary areas than the EAPS. Both pump stations are configured with identical primary and backup pumps that can be used during normal operation. The Locus Point Pump Station has two pumps with capacities of 0.9 MGD that discharge to a 10-inch force main before conveying flows into a 10-inch gravity sewer. The McComas Pump Station has two pumps with capacities of 0.48 MGD that discharge to a 6-inch force main before conveying flows into an 18-inch gravity sewer. Table 2 below summarizes the peak flows and velocities for each pump station.

Table 2 – Locust Point and McComas Pump Station Results (Baseline)

Design Storm	Locust Point			McComas Street		
	Peak Incoming Flow Rate (MGD)	Peak Discharge (MGD)	Peak Velocity (fps) in 10" FM	Peak Incoming Flow Rate (MGD)	Peak Discharge (MGD)	Peak Velocity (fps) in 8" FM
DWF	0.42	0.90	1.53	0.16	0.48	2.09
3-month	0.74	0.90	1.52	0.47	0.48	2.01
1-year	1.27	1.75	2.33	0.90	0.97	3.25
2-year	1.56	1.79	2.52	1.10	0.97	2.85
5-year	1.96	1.81	2.32	1.36	0.97	2.85
10-year	2.31	1.81	2.34	1.58	0.97	3.27
15-year	2.50	1.81	2.52	1.70	0.97	2.84
20-year	2.68	1.81	2.40	1.82	0.97	3.27

The velocities remain below 7 fps for both pump stations under all design storm scenarios.

3.3.5 Baseline Predicted Sanitary Sewer Overflows

During dry weather flows there are no overflows in the Low Level sewershed. However, beginning at the 1-year, 24-hour storm event, SSOs begin to occur. The overflows begin during the 1-year design storm as shown in Figure 6. These figures show the smallest storm event during which overflows just begin to occur. SSO volumes for each individual modeled manhole during the design storms for Scenario 1 and 2 are listed in Appendix A.

Table 3 – Baseline System-Wide Predicted SSO Volumes

Design Storm	Five Pumps Available at EAPS (MG)	Four Pumps Available at EAPS (MG)
DWF	0.00	0.00
3-month	0.01	0.01
1-year	2.09	2.10
2-year	3.45	3.46
5-year	6.25	6.29
10-year	8.86	9.03
15-year	10.44	10.61
20-year	12.06	12.41

3.3.6 Baseline Hydraulic Restrictions

One of the requirements of the CD is to identify and map all components of the wastewater collection system that restrict flow of wastewater through the collection system that cause or contribute to, or are likely to cause or contribute to, overflows from the collection system. InfoWorks CS has the ability to determine system components that restrict flow, thus potentially leading to an overflow. This analysis is performed by the software, where the slope of each sewer segment is compared to the slope of the hydraulic grade line at peak flow. A surcharged sewer with a pipe slope that is flatter than the slope of the hydraulic grade line indicates that the sewer is restricting flow, i.e., a bottleneck. If the pipe slope is steeper than the slope of the hydraulic grade line, then the surcharge is not necessarily caused by a capacity limitation in that pipe. This indicates that the sewer segment is in a backwater condition caused by a downstream control. Figure 7 depicts the results of this analysis, showing the smallest storm event restriction leading to an upstream overflow. A summary of pipe sizes and cumulative lengths identified are shown in Table 4. For simplicity this analysis was conducted for assuming all five pumps available.

Most of the pipe capacity deficiencies are due to excessive inflow/infiltration into the system (hydraulic capacity). However, there are a few locations where construction defects and maintenance issues are the main culprit of SSOs.

Table 4 – Baseline Hydraulic Flow Restriction Lengths (ft) by Pipe Diameter

Pipe Diameter	3-month	1-year	2-year	5-year	10-year	15-year	20-year
<10”	262	2,845	5,148	8,172	9,640	10,650	10,951
10” - 19”	1,630	12,383	18,622	32,688	41,301	46,985	50,945
20” – 29”	909	7,153	13,016	18,316	20,565	22,371	23,282
30” – 39”	2,863	10,327	10,917	12,161	12,294	12,152	11,919
>40”	6,166	12,715	13,679	13,745	14,914	15,940	15,940
Total Length	11,830	45,423	61,382	85,082	98,714	108,098	113,037

Table 5 illustrates the percentage of pipes of each size category that are restricting flow.

Table 5 – Baseline Hydraulic Flow Restrictions by Percent of Respective Pipe

Pipe Diameter	3-month	1-year	2-year	5-year	10-year	15-year	20-year
<10”	0.5%	5.3%	9.5%	15.2%	17.9%	19.8%	20.3%
10” - 19”	0.6%	4.2%	6.3%	11.0%	13.9%	15.9%	17.2%
20” – 29”	1.3%	10.5%	19.1%	26.8%	30.1%	32.7%	34.1%
30” – 39”	12.2%	44.2%	46.7%	52.0%	52.6%	52.0%	51.0%
>40”	18.2%	37.6%	40.5%	40.7%	44.1%	47.2%	47.2%
Total Length	2.5%	9.5%	12.9%	17.9%	20.8%	22.7%	23.8%

Another significantly contributing factor for the flow restrictions along the East and West Interceptor is the presence of large amounts of sediment. The downstream portions of these interceptors are subject to backwater effects from pump operations at the EAPS. This backwater effect causes these areas to have very low flow velocities (often less than 1 fps) resulting in the sediment being carried by the flow to drop out and build up in the pipe. In the worst cases, up to one third of the total pipe diameter is blocked by sediment dramatically reducing the flow carrying capacity of the interceptors. This also results in side branches that connect to these interceptors to back up as a result.

4.0 Future Analysis and Capacity Assessment

4.1 General

The future conditions model is based on an estimate of the collection system in the year 2025. The future conditions model includes future projections for populations and jobs based on data provided by the Baltimore Metropolitan Council. The hydraulic impact of pipe deterioration has been represented by increasing groundwater infiltration by 10% compared to baseline conditions. Finally, expected capital improvement projects expected to be completed before the future conditions year.

The future conditions model has been simulated during both dry weather and wet weather conditions to identify areas of the Low Level collection system which lack adequate capacity to pass the projected flows for the various storm events. The wet weather storm events modeled for the future conditions are the same as those simulated for the baseline analysis. These design storms include the 3-month, 6-hour event and the 1-, 2-, 5-, 10-, 15, and 20-year, 24 hour storms. Maps have been created showing the results of the return period analysis and hydraulic flow restrictions.

4.2 Future Dry Weather Capacity Assessment

An assessment of the future conditions model for dry weather capacity was completed and there are no overflows in the system during dry weather. However, there are portions of the collection system that do experience surcharge conditions during peak dry weather flows. The location of these surcharge conditions are highlighted in red as shown on Figure 8. Figure 8 displays the peak percent full for each pipe during dry weather. Surcharge conditions are most pronounced along the East Interceptor in the vicinity of the EAPS. The pipes that are 75 percent full or greater during peak dry weather flows are highlighted in orange on Figure 8. A pipe that is ¾ full during dry weather does not provide adequate capacity for future growth or wet weather flows. The pipe segments that are between 50-75 percent full during dry weather are highlighted in yellow on Figure 8. The main causes of the elevated water levels are generally that the EAPS wet well operates at a high elevation and this causes a backup effect for a distance up both the east and west interceptors.

4.3 Future Wet Weather Capacity Assessment

4.3.1 Storm Events

The storm events used in the future conditions were the same as was used in the baseline conditions. As stated earlier, there are seven design storms that were to be analyzed. These design storms included a 3-month, 6-hour design storm and the 1, 2, 5, 10, 15, and 20-year, 24 hour duration storms.

4.3.2 Future Return Period Analysis

A Return Period Analysis (RPA) was performed for each the seven design storms for future conditions just as for the baseline conditions. In doing this, InfoWorks compares the surcharge state of the sewer system and any flooding based on each design storm and presents the minimum size storm required to surcharge and flood (cause an overflow) a pipe segment, along with the estimated flood volume. This is accomplished by selecting all of the simulations based on the design storms and loading them into the Grid Report results menu and selecting the RPA option in InfoWorks CS. The results of the future conditions flooding RPA are presented in Figure 9.

4.3.3 Eastern Avenue Pumping Station Analysis (Future)

The operation of the EAPS is the same for the future conditions as for the baseline. Both models include the effects of the ongoing upgrade to add SCADA connectivity for the station and the addition of operational control logic for the station's five primary constant speed pumps. The new control logic for the pumps will tie the on/off operation of each pump to defined wet well elevations. The control logic includes the following rules:

- **Lead Pump** On Level: -6.5 Off Level: -11
- **Lag Pump 1** On Level: -6.0 Off Level: -10.5
- **Lag Pump 2** On Level: -5.5 Off Level: -10.0
- **Lag Pump 3** On Level: -5.0 Off Level: -9.5
- **Lag Pump 4** On Level: -4.5 Off Level: -9.0

Initially, different pump sequences are defined for four different operational conditions: Dry Weather Conditions (Daytime and Evening) and Wet Weather Conditions (Daytime and Evening).

For the future conditions assessment, two EAPS modeling scenarios were developed as per the BaSES manual:

- Scenario 1 - all five primary pumps were available; and
- Scenario 2 - four primary pumps available with one backup offline

These two scenarios were simulated for each of the seven design storms. This setup assumes that the collection system downstream of the EAPS (Outfall Basin) can accept the peak wet weather flows from the EAPS with up to five pumps operating at once. Once all of the individual sewershed models are combined for further analysis by the Technical Program Manager, an evaluation should be conducted to verify the flows can be handled by the collection system in the Outfall sewershed. The peak flow rates and force main velocities for the EAPS are presented below in Table 6. For the 15-year and greater storm events (five pump scenario) and for the 5-year and greater storms events (four pump scenario), velocities fractionally in excess of 7 fps were identified.

Table 6 – Eastern Avenue Pump Station Results (Future)

Design Storm	Peak Incoming Flow Rate (MGD)	Five Pumps Available			Four Pumps Available		
		Peak Discharge (MGD)	Peak Velocity (fps) in 42" FM	Peak Velocity (fps) in 60" FM	Peak Discharge (MGD)	Peak Velocity (fps) in 42" FM	Peak Velocity (fps) in 60" FM
DWF	59.8	39.4	not used	2.4	39.4	not used	2.0
3-month	64.7	80.8	not used	4.5	77.1	not used	4.5
1-year	96.8	109.5	3.5	4.5	104.9	not used	5.9
2-year	111.2	137.2	3.4	4.5	104.9	not used	5.9
5-year	129.2	137.2	3.5	6.0	127.9	not used	7.1
10-year	141.1	137.2	3.5	6.0	127.9	not used	7.1
15-year	146.0	160.5	3.5	7.1	127.9	not used	7.1
20-year	150.3	160.5	3.5	7.1	127.9	not used	7.1

4.3.4 Other Modeled Pump Stations (Future)

Two other pump stations were included in the Low Level model, and are the Locust Point Pump Station and the McComas Pump Station. These pump stations are both located upstream in the collection system and serve much smaller tributary areas than the EAPS. For the purposes of analyzing future conditions scenarios, both pump stations were considered to operate as currently configured. Both pump stations are configured with identical primary and backup pumps that can be used during normal operation. The Locus Point Pump Station has two pumps with capacities of 0.9 MGD that discharge to a 10-inch force main before conveying flows into a 10-inch gravity sewer. The McComas Pump Station has two pumps with capacities of 0.48 MGD that discharge to a 6-inch force main before conveying flows into an 18-inch gravity sewer. Table 7 below summarizes the peak flows and velocities for each pump station.

Table 7 – Locust Point and McComas Pump Station Results (Future)

Design Storm	Locust Point			McComas Street		
	Peak Incoming Flow Rate (MGD)	Peak Discharge (MGD)	Peak Velocity (fps) in 10" FM	Peak Incoming Flow Rate (MGD)	Peak Discharge (MGD)	Peak Velocity (fps) in 8" FM
DWF	0.42	0.90	1.53	0.16	0.48	2.09
3-month	0.75	0.90	1.53	0.47	0.95	3.25
1-year	1.29	1.76	2.33	0.90	0.97	2.85
2-year	1.57	1.79	2.33	1.10	0.97	3.25
5-year	1.98	1.81	2.35	1.36	0.97	2.76
10-year	2.33	1.81	2.52	1.58	0.97	2.74
15-year	2.52	1.81	2.59	1.71	0.97	3.25
20-year	2.70	1.81	2.59	1.82	0.97	3.23

As shown in Table 7, the velocities remain below 7 feet per second for both pump stations under all design storm scenarios.

4.3.5 Future Predicted Sanitary Sewer Overflows

During dry weather flows there are no overflows in the Low Level sewershed. However, beginning at the 1-year, 24-hour storm event, SSOs begin to occur. The overflows begin during the 1-year design storm as shown in Figure 9. These figures show the smallest storm event during which overflows just begin to occur. Under both pump station scenarios (i.e. five pumps and four pumps), the SSO volumes for all modeled manholes for each of the design storms evaluated are summarized in Table 8. SSO volumes for each individual modeled manhole during the design storms for Scenario 1 and 2 are listed in Appendix A.

Table 8 – Future System-Wide Predicted SSO Volumes

Design Storm	Five Pumps Available at EAPS (MG)	Four Pumps Available at EAPS (MG)
DWF	0.00	0.00
3-month	0.00	0.00
1-year	1.71	1.73
2-year	2.88	2.92
5-year	4.97	5.09
10-year	7.37	7.69
15-year	8.67	9.19
20-year	9.94	10.66

4.3.6 Future Hydraulic Restrictions

One of the requirements of the CD is to identify and map all components of the wastewater collection system that restrict flow of wastewater through the collection system that cause or contribute to, or are likely to cause or contribute to, overflows from the collection system. InfoWorks CS has the ability to determine system components that restrict flow, thus potentially leading to an overflow. This analysis is performed by the software, where the slope of each sewer segment is compared to the slope of the hydraulic grade line at peak flow. A surcharged sewer with a pipe slope that is flatter than the slope of the hydraulic grade line indicates that the sewer is restricting flow, i.e., a bottleneck. If the pipe slope is steeper than the slope of the hydraulic grade line, then the surcharge is not necessarily caused by a capacity limitation in that pipe. This indicates that the sewer segment is in a backwater condition caused by a downstream control. Figure 10 depicts the results of this analysis, showing the smallest storm event restriction leading to an upstream overflow. A summary of pipe sizes and cumulative lengths identified are shown in Table 9. For simplicity this analysis was conducted for all five pumps available.

Most of the pipe capacity deficiencies are due to excessive inflow/infiltration into the system (hydraulic capacity). However, there are a few locations where construction defects and maintenance issues are the main culprit of SSOs.

Table 9 – Future Hydraulic Flow Restriction Lengths (ft) by Pipe Diameter

Pipe Diameter	3-month	1-year	2-year	5-year	10-year	15-year	20-year
<10”	269	2,997	5,502	8,695	9,873	10,965	11,475
10” - 19”	1,630	12,967	19,489	32,322	42,946	48,984	51,755
20” – 29”	1,131	7,087	13,019	19,559	21,177	22,367	23,674
30” – 39”	2,856	8,710	10,389	12,225	12,809	13,149	12,941
>40”	2,561	8,078	8,245	12,440	13,530	15,714	15,714
Total Length	8,447	39,839	56,644	85,241	100,335	111,179	115,559

Table 10 illustrates the percentage of pipes in the hydraulic model of each size category that are restricting flow.

Table 10 – Future Hydraulic Flow Restrictions by Percent of Respective Pipe

Pipe Diameter	3-month	1-year	2-year	5-year	10-year	15-year	20-year
<10”	0.5%	5.6%	10.2%	16.1%	18.3%	20.3%	21.3%
10” - 19”	0.6%	4.4%	6.6%	10.9%	14.5%	16.5%	17.5%
20” – 29”	1.7%	10.4%	19.1%	28.6%	31.0%	32.7%	34.6%
30” – 39”	12.2%	37.3%	44.4%	52.3%	54.8%	56.2%	55.3%
>40”	7.6%	23.9%	24.4%	36.8%	40.0%	46.5%	46.5%

Total Length	1.8%	8.4%	11.9%	17.9%	21.1%	23.4%	24.3%

Another significantly contributing factor for the flow restrictions along the East and West Interceptor is the presence of large amounts of sediment. The downstream portions of these interceptors are subject to backwater effects from pump operations at the EAPS. This backwater effect causes these areas to have very low flow velocities (often less than 1 fps) resulting in the sediment being carried by the flow to drop out and build up in the pipe. In the worst cases, up to one third of the total pipe diameter is blocked by sediment dramatically reducing the flow carrying capacity of the interceptors. This also results in side branches that connect to these interceptors to back up as a result.

5.0 Summary and Conclusions

This report concludes the evaluation of the Low Level sewershed collection system for both the baseline and future conditions as defined by the CD and the BaSES Manual. The results generally show that the causes of surcharging and flooding conditions are largely the result of the operation of the EAPS (though not its pumping capacity) and local bottlenecks throughout the collection system. These results of the analyses described in this report from the basis for evaluating potential system improvements to eliminate the collection system limitation and reduce or eliminate surcharging and flooding conditions.